THE CAUSE OF
EROSION IN THE
FINNEY FARM AREA

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ABSTRACT

Erosion on the Finney Farm by Dry Creek has been excessive. Many variables of erosion contribute to the instability of the area such as topography, geologic setting, soils, vegetation, and climate. However, an external stimulus is needed to cause the instability seen in this river system. External stimuli include climatic changes, tectonics, isostatic rebound, or the influence of man. The influence of man had the most effect on the Dry Creek area because of gravel removal and a straightening of the stream channel. These two influences increased the slope in the basin and caused the excessive erosion seen in the area.

INTRODUCTION

Significance and Purpose

In order to classify the development of river systems, Davis, in 1899 came up with a description of the life stages in the erosion cycle of a landscape. Most geologists today accept this classification system for describing the evolutionary development of a landscape but consider the concept of dynamic equilibrium to describe the modern landscape (Schumm, 1973). Dynamic equilibrium can be defined as a "temporal scale of channel adjustment" (Richards,1982; Dury, 1966).

In order for a change to occur in this dynamic system a geomorphic threshold must be reached (Schumm, 1973). This threshold can only be reached if a system has evolved to a critical situation. After this critical situation is reached, adjustment or failure will occur.

Dry Creek in Licking County is an area where change has occurred and a geomorphic threshold has been reached (Figure 1). The changes seen in the Finney Farm area and downstream from it have been dramatic in the last twenty years. Between 1976 and 1983, the difference between the elevation of the stream and the high point on the bank increased ten feet and the meandering of the stream destroyed 2.02 acres of Finney's property with 0.14 of those acres prime agricultural land (Finney, 1983). If Dry Creek continues its destructive course, the housing area across the stream may also be endangered (figure 2).

Figure 1. The river bend of Dry Creek where erosion of the Finney Farm has occured. View is upstream of the farm.

Figure 2. The housing establishment upstream and and across the river from the big bend. If erosion by Dry Creek continues at its present rate, this person may loose his house in another ten years.

The purpose of this report is to access the variables contributing to the erosion of the Finney property and examine the possible causes.

Limitations

This report only deals with the variables and causes of erosion on the Finney farm. No methods for stopping the erosion are discussed.

Scope

This report is divided into four categories. These categories discuss variables and causes of erosion on the Finney property and include the influence of basin characteristics, the development of historical trends, river mechanics, and drainage-basin studies.

Procedure

First, basin elements, such as the topography, the geologic setting, the soil, and the climate of the Dry Creek area were analyzed. Then aerial photographs were examined to determine historical trends in erosion. Velocity measurements were made in April and May to determine discharge and its influence on the basin. Finally, under Drainage-Basin Studies, possible causes of the instability of the drainage basin in the Finney Farm area are discussed.

ELEMENTS AFFECTING EROSION IN THE RIVER SYSTEM

Many variables interact to contribute to erosion in a river system. Table 1 lists these variables and shows their relationship. Patrick, Smith, and Whitten(1982)

Table 1. Relationship between dependent and independent variables in a river system (from D.M. Patrick, L.M. Smith, and C.B. Whitten. "Methods for studying accelerated fluvial change." In R.D. Hey (Ed.), Gravel-Bed Rivers, New York: John Wiley & Sons, 1982).

Independent and influencing variables \ Dependent variables	Soils	Landalides	Vegetation	Topography	Sediment yield	Runoff	Channel widening	Channel deepening	Sinuosity changes	Flow	Channel width	Channel depth	Channel slope	Bank materials	Sediment discharge	Flows (Basin)	Bank erosion
$\boxed{\text{Flow}}$							X	X	X		$\boxed{X}$	$\boxed{X}$	$\boxed{X}$	$\boxed{X}$	$\boxed{X}$		
Topography	X	X	X			X										X	
$\boxed{\text{Sediment discharge}}$							X	X	X		$\boxed{X}$	$\boxed{X}$	$\boxed{X}$	$\boxed{X}$			
Soils		X	X		X	X											
Climate*	X		X	X		X											
$\boxed{\text{Bank materials}}$							X	X	X	$\boxed{X}$							
Lithology*	X	X		X													
Flows (basin)		X			X					X							
Landslides	X			X	X												
Vegetation	X				X	X											
Runoff		X			X											X	
Forestry*	X		X														
Roads*			X	X													
Structure/tectonics*		X		X													
Grazing*			X														
$\boxed{\text{Channel width}}$										$\boxed{X}$							
$\boxed{\text{Channel depth}}$										$\boxed{X}$							
$\boxed{\text{Channel slope}}$										$\boxed{X}$							
Channel widening																	X
Channel deepening																	X
Sinuosity changes																	X
Sediment yields															$\boxed{X}$		

* Independent variables.
$\boxed{\text{Flow}}$ Site factors.
X Link between variables.
X Links between site and non-site factors.

divide causes and variables of river erosion into four categories. These categories are (i) the influence of basin characteristics (topography, geologic setting, soils, climate, and vegetation), (ii) the development of historical trends, (iii) river mechanics, and (iv) drainage-basin studies.

The Influence of Basin Characteristics

Topography and geologic setting. Licking County is located in central Ohio. Central Ohio consists mainly of plains and rolling lowlands reflecting the mantle of continuous glacial drift. Most of this glacial drift is left from the Illinoian and Wisconsinian glaciations.

Dry Creek in the Finney Farm area is cut into a glacial outwash terrace of Wisconsinan age. This outwash has a silt cap of two to three feet and is well-sorted. Because the topography has low relief it is not very influential in the erosion of the Finney property. Rill and gully erosion is also minimal because of the high infiltration capacity of glacial outwash. Glacial outwash, however, is conducive to some erosion processes. Mass movement tends to occur in outwash terraces because the erosion process does not have to overcome cohesion between the grains. Evidence of mass movement is seen in the Finney Farm area (Figure 3).

Soils and vegetation. As mentioned above, the Finney Farm is located in a glacial outwash terrace. Because glacial outwash is rich in minerals it encourages the growth of vegetation and is ideal for farming. Farming usually helps to increase erosion because it increases surface runoff. Because the soil is derived from glacial

Figure 3. Evidence of mass movement occurring on the Finney property due to high infiltration capacity in noncohesive, well-sorted glacial outwash.

outwash, it too increases erosion because it allows the percolation of surface water and flowage of groundwater through it, thus increasing the chance of slope failure.

Climate. Ohio experiences a fairly mild climate, with an average of 36 inches of precipitation a year. Climate affects erosion mostly in the spring when snowmelt and freeze-and-thaw processes predominate.

Climate, soil, vegetation, topography, and geologic setting are all important controlls in erosion. However, independently they would not cause a significant change in a river system. In order for a change to occur in a river system in dynamic equilibrium, an application of an external stimulus is needed. To determine if this change had occurred in the Finney Farm area, historical data had to be analyzed and river mechanics examined.

Historical Data

Historical data are needed to determine trends or significant changes in the drainage area. In the case of Dry Creek, aerial photographs from 1934,1940, 1958, 1964, 1970, 1976, 1981, and 1983 were used to document the geomorphic changes. Figures 4 and 5 illustrate changes occurring between 1934 and 1940. The 1934 view shows approximately stable conditions with tree-lined banks, minor point bar accretion, and no apparent sediment accumulation. In the 1940 aerial photograph, stable conditions are still apparent on the big-bend of Dry Creek

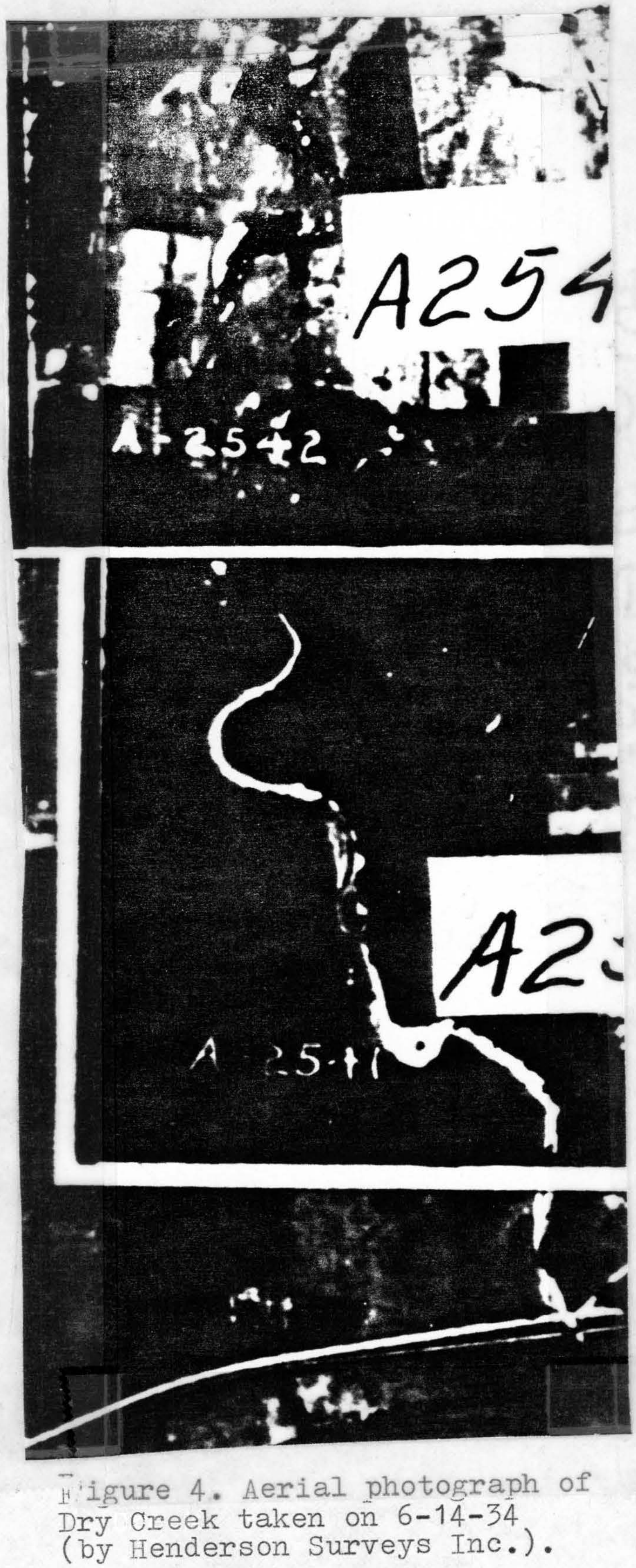

Figure 4. Aerial photograph of Dry Creek taken on 6-14-34 (by Henderson Surveys Inc.).

Figure 5. Aerial photograph of Dry Creek taken on 7-14-40 (by Henderson Surveys Inc.).

on the Finney Farm, but downstream point bar enlargement is apparent. The change in enlargement and instability downstream is even more evident in the 1958 view (Figure 6). This view of the river downstream suggests that a geomorphic threshold has been reached since the nature of the stream has changed from meandering to braided (Schumm, 1973). In the 1964 view we first begin to see a change in the Finney Farm big-bend; the point bar is enlarging (Figure 7). This new change shows that degradation is migrating upstream. From the view taken in 1964 to the view taken in 1970 a significant change has occurred (Figure 8). The two meanders directly downstream from the Finney Farm have been cut-off and the rate of degradation and instability seems to have increased. The 1970 view to the 1983 view shows the greatest degradation and instability in the Finney Farm area with the downstream reaches beginning to stabilize (figures 8, 9, 10, and 11).

River Mechanics

An important aspect in determining the erosion of the Finney Farm is to consider the river mechanics. Both discharge and sediment load can affect erosion.

Discharge. Since no previous measurements of discharge had been made, no conclusions could be made concerning the stream's discharge and its influence on the erosion of the big-bend on the Finney property. However, velocity measurements were taken and discharge calculated

Figure 6. Aerial photograph of Dry Creek taken on 8-5-58(by Henderson Surveys Inc.).

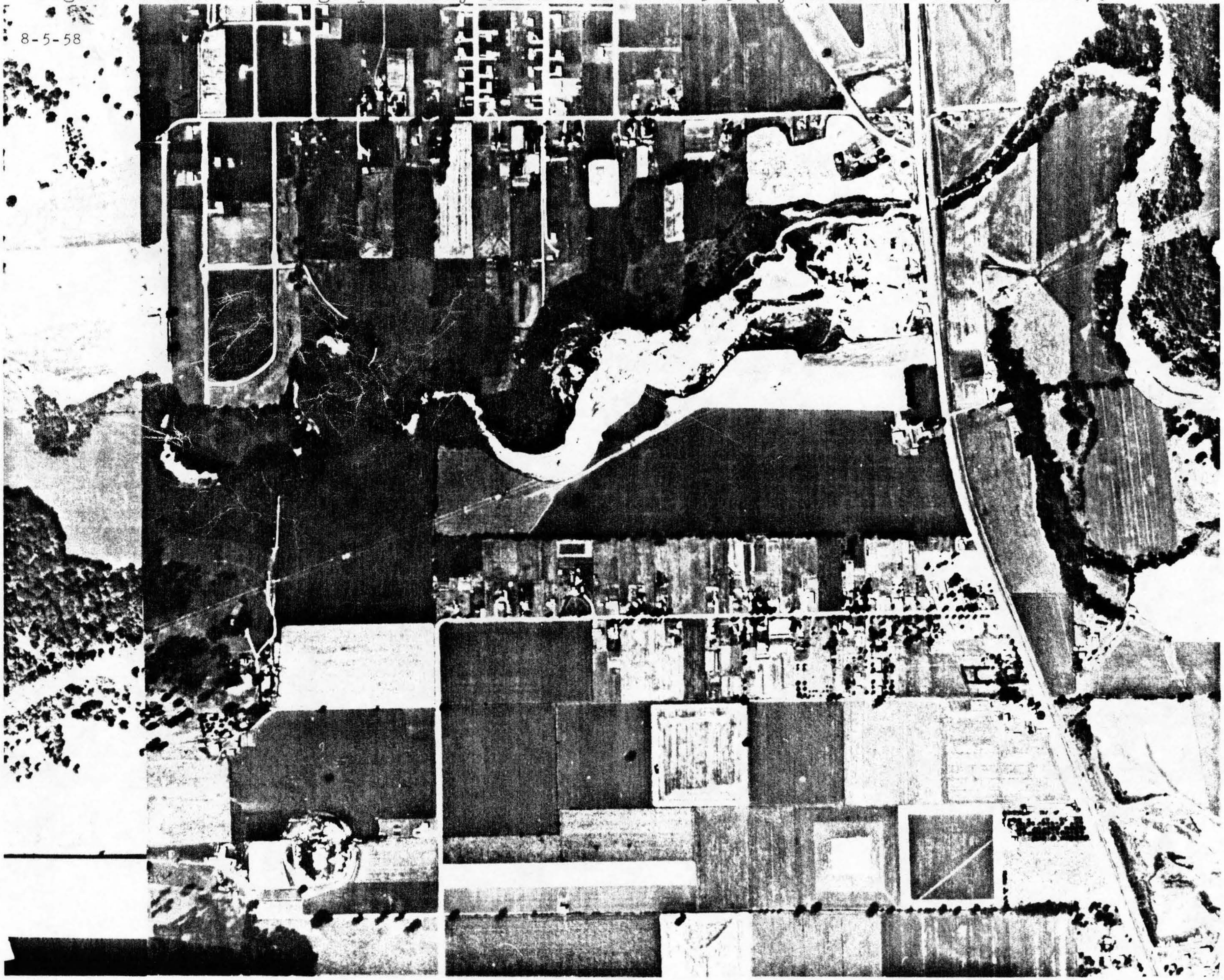

Figure 7. Aerial photograph taken in 1964 by Henderson Srveys Inc. The point bar on the Finney property is enlarging.

Figure 8. Aerial photograph taken in 1970 by Henderson Surveys Inc. Notice the cut-off of the two meanders that occurred since 1964.

Figure 9. Aerial photograph of Dry Creek taken in 1976 (by Henderson Surveys Inc.). Notice that the downstream reaches from Finney Farm are beginning to stabilize.

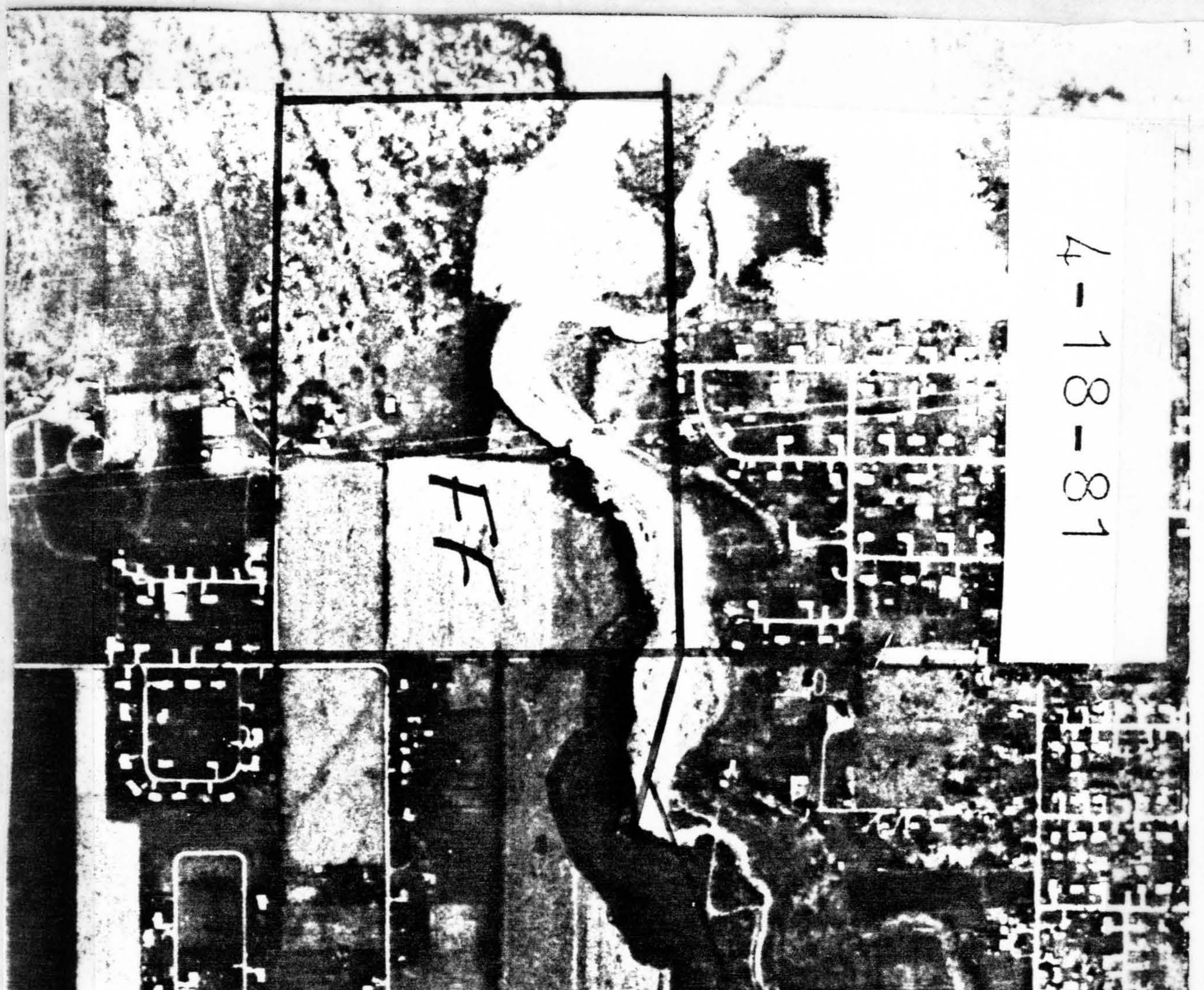

Figure 10. Aerial photograph of Dry Creek taken in 1981 (by Henderson Surveys Inc.) Degradation in the Finney Farm area has increased significantly since the aerial photo taken in 1976.

Figure 11. Aerial photograph of Dry Creek taken in 1983 (by Henderson Surveys Inc.). Maximum degradation is now occurring in the Finney Farm area.

for the month's of April and May (see figures 12 and 13). These calculations can be used in the future to determine if an increase in the velocity of the stream is a factor in the bank erosion. Two methods were used for calculating discharge.

Method I. The equation for the flow of water through a cross-section can be written

$$Q = VA$$

where Q is the rate of flow, A is the cross-sectional area, and V is the average velocity of the stream. I measured the velocity by employing the float method. By marking off a certain distance, I calculated the time it took for a float to get from one point to another. Because the velocity at the surface exceeds the average velocity for a given vertical profile of the stream, I multiplied the surface velocity by 0.85 to obtain the average velocity(Bowen, 1982). The discharge was then calculated by multiplying the velocity by the cross-sectional area.

Method II. Manning's Equation may be written as:

$$V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

where V = mean velocity

R = hydraulic radius

S = hydraulic gradient

n = coefficient of roughness

I used n = 0.03 (roughness for cobbles and gravel) and determined the slope and cross-sectional area by direct measurements in the stream bed. Discharge was then cal-

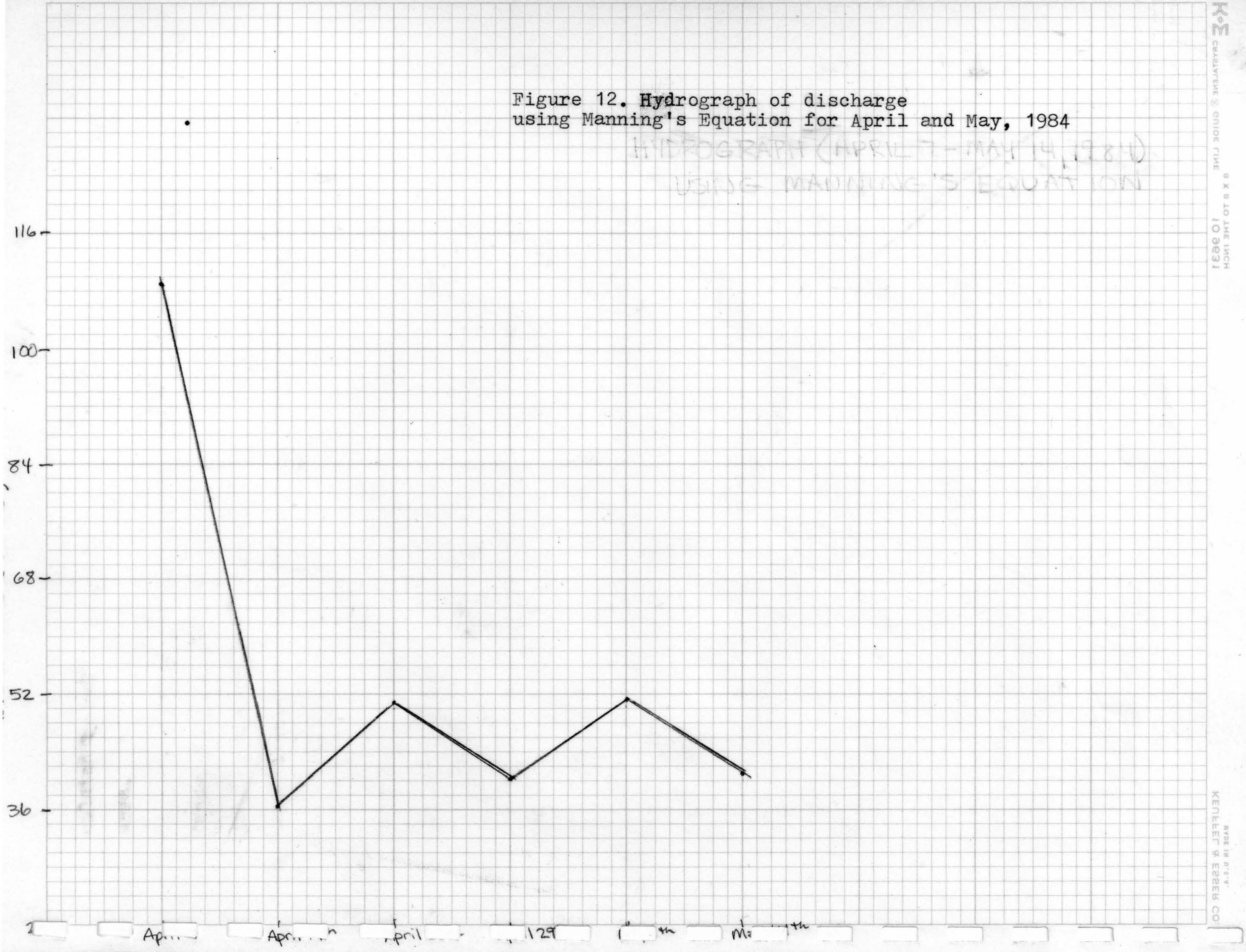

Figure 12. Hydrograph of discharge using Manning's Equation for April and May, 1984

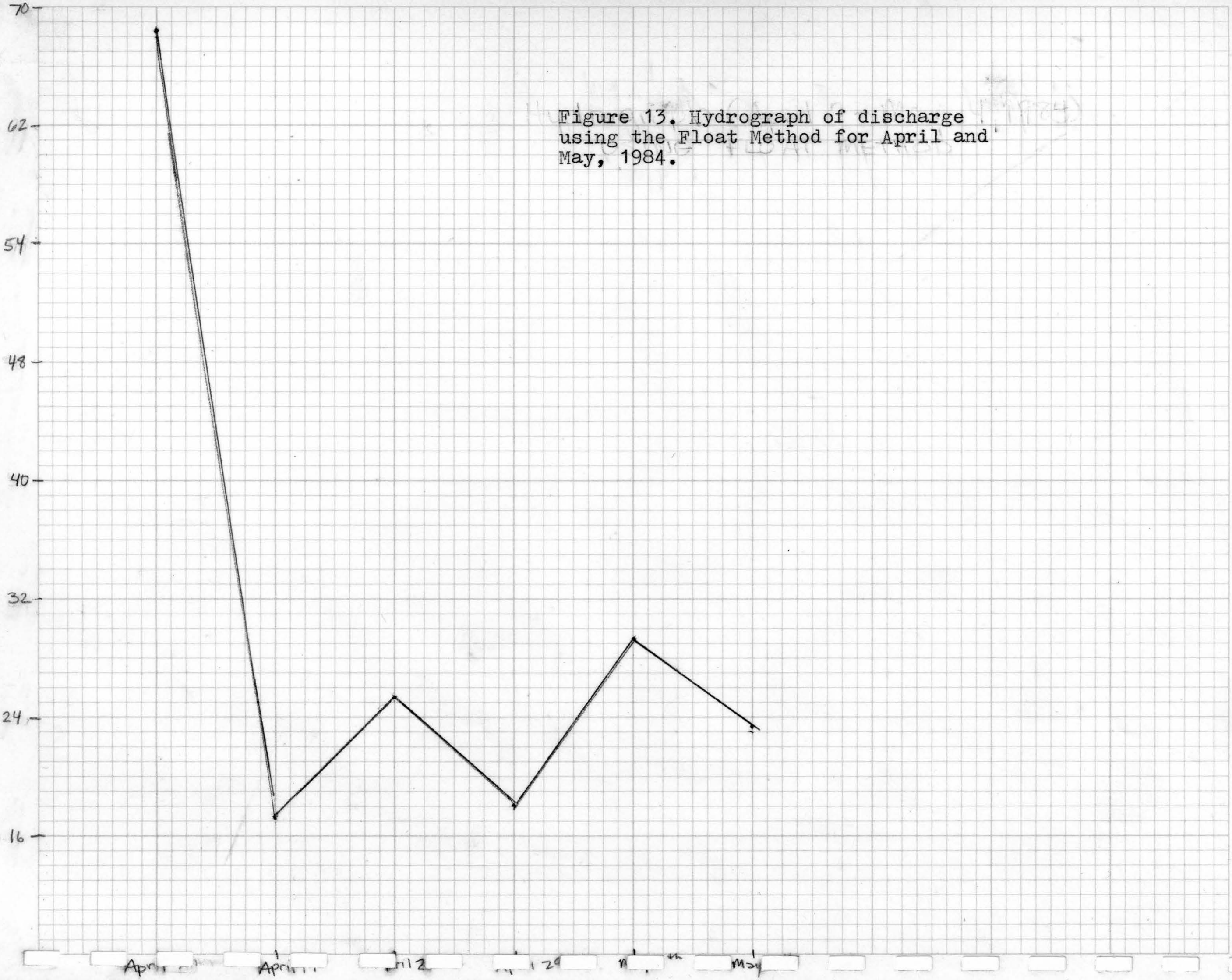

Figure 13. Hydrograph of discharge using the Float Method for April and May, 1984.

culated by multiplying the velocity by the cross-sectional area.

Sediment load. Sediment load is also an important factor in bank erosion. The larger the particles, the greater the erosion along the bank. No field measurements were taken of sediment load. However, in 1983, H.R. Finney used Hack's formula

$$S = K\left(\frac{d}{A}\right)^{0.6}$$

where S = slope of channel in feet per mile

K = (constant) 18

d = median size of particle transported

A = Area of watershed in square miles

and deduced that in 1962 the median size of a particle transported by Dry Creek was 1.57 inches, whereas in 1983, the median size of a particle transported by the stream was 3.4 inches. Hack's formula was used because it is an empirical slope equation based on rivers in Virginia, and Virginia is the closest locality to central Ohio with a determined empirical slope equation. Even though an increase in particle size would create more erosion along the Dry Creek river bend, limitations of this conclusion should be considered because of the difference in locality.

Drainage-Basin Studies

A study of the drainage basin is made after accessing the erosion factors to determine what the cause of erosion is. For the geomorphic change of Dry Creek and the change in the rate of erosional processes to occur, an external stimulus had to have been applied. External stimuli that would create a geomorphic change are the influence of man, climatic changes, tectonics, or isostatic adjustments.

Climatic changes. Some major erosional adjustments can be caused by fairly insignificant events. If a river system is near a geomorphic threshold, one storm or one flood could cause it to cross that threshold, creating a great change in the rate of erosion. To estimate the effect of flooding, I examined the maximum discharge record from 1940-1981 of the Licking River near Newark (compiled by H.R. Finney, 1983). I assumed that the peak flow of Dry Creek was directly proportional to the peak flow of Licking River. The four greatest daily and monthly discharge amounts occurred before 1964 (Figure 14). Since the greatest increase in erosion has been in the 1970's one flood event could be ruled out as a significant factor in the instability and erosion of Dry Creek.

Tectonics. Licking County is in a relatively stable area, geologically. No faults were found in the vicinity of Dry Creek and there have been no significant earthquakes in the area within the last 40 years. Therefore, tectonics can be ruled out as a possible cause for the excessive erosion.

Isostatic adjustments. Because Licking County

Figure 14. Streamflow for Licking River near Newark in ft^3 sec^{-1}. (Compiled by H.R.Finney, 1983). The numbers in parantheses represent the 4 greatest daily and monthly discharges between 1964 and 1981.

	Daily		Monthly	
Water year (Oct-Sept)	Month	Am't.	Month	Am't.
1940	Apr.	16,500	Apr.	72,117
1941	Dec.	3,150	June	17,076
1942	Apr.	5,170	Feb.	30,452
1943	Mar.	13,000	Jan.	57,562
1944	Mar.	8,260	Mar.	46,877
1945	Mar.	15,000	Mar.	102,564 (2)
1946	Feb.	6,420	Mar.	41,277
1947	Jan.	7,280	May	56,760
1948	Feb.	11,700	Apr.	56,807
1949	Jan.	7,500	Jan.	65,744
1950	Jan.	10,800	Jan.	90,713 (3)
1951	Jan.	12,000	Jan.	58,638
1952	Jan.	20.300 (4)	Jan.	79,071 (4)
1953	July	2,810	Apr.	12,434
1954	Apr.	3,320	Apr.	17,040
1955	Mar.	5,940	Mar.	43,439
1956	June	8,590	Feb.	46,294
1957	Apr.	9,080	Apr.	49,285
1958	May	7.040	Dec.	42,538
1959	Jan.	25,600 (1)	Jan.	71,492
1960	Feb.	7,350	Feb.	35,626
1961	Apr.	8,470	Mar.	53,498
1962	Mar.	6,610	Mar.	45,269
1963	Mar.	21,100 (3)	Mar.	107,071 (1)
1964	Mar.	21,300 (2)	Mar.	75,925
1965	Apr.	5,300	Apr.	52,215
1966	Apr.	5,110	May	32,687
1967	Mar.	7,690	Mar.	63,577
1968	May	16,100	May	77,294
1969	June	10,000	Jan.	40,577
1970	Apr.	9,990	Apr.	63,286
1971	Feb.	4,790	Feb.	37,638
1972	Apr.	4,890	Apr.	46,229
1973	Nov.	5,750	Nov.	51,318
1974	Nov.	9,880	Jan.	44,482
1975	Feb.	14,800	Feb.	53,440
1976	Feb.	5,230	Feb.	38,442
1977	Apr.	5,630	Mar.	34,852
1978	Mar.	10,200	Mar.	64,781
1979	Sept.	15,200	Sept.	66,199
1980	Aug.	7,660	Mar.	47,286
1981	Apr.	9,190	Feb.	52,459

was covered by glaciers about 15,000 years ago, one possible explanation for the significant geomrphic change of Dry Creek deals with isostatic rebound. Perhaps some rebounding of the earth's crust is still occurring in this area causing the river to cut down into the sediments as the crust uplifts. However, contemporary deformation in the Northeast is only occurring as far south as Lake Erie(Figure 15). Therefore, isostatic rebound can be ruled out as a major cause in the instability of Dry Creek.

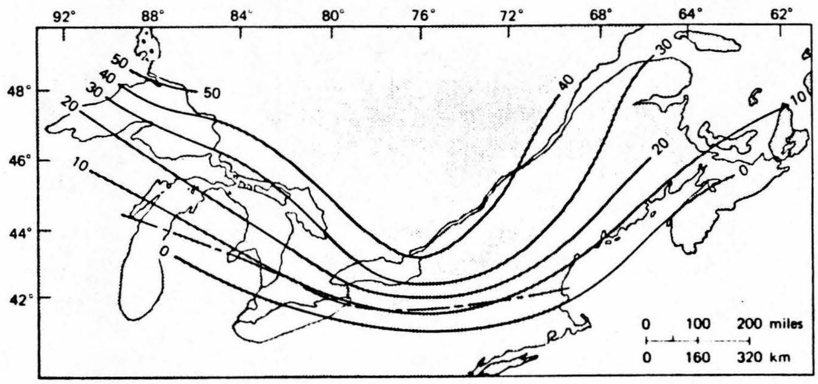

Figure 15. Contemporary deformation in eastern North America. The lines represent amplitude of crustal warping (from Karl K. Turekian (Ed.), The Late Glacial Ages, New Haven: Yale University Press, 1971).

Influence of man. Man can also act as an external stimulus influencing the river system. In the case of Dry Creek, two man-induced actions, the excavation of bed material, and the two meander cut-offs, could have created the adverse erosional effects seen on Dry Creek.

The Removal of Bed Material. The removal of bed material, or gravel mining can lead to upstream erosion because flattening of the downstream slope requires a lowering of the river bed (Galay, 1983). This lowering of the river bed and base level causes incision to progress upstream (Schumm, 1973). Figure 16 shows the response of a channel to base lowering. The formation of terraces, the braided character of Dry Creek directly downstream from the Finney farm, and the formation of a floodplain at a lower level are characteristics of Dry Creek that suggest base lowering is occurring. Gravel has been removed from the stream bed directly downstream from the Finney Farm since the mid 1940's.

The Cut-off of Meanders. The cut-off of two meanders directly downstream from Finney Farm occurred sometime between 1964 and 1970 (see Figures 7 and 8). According to Galay (1983) the creation of a cut-off causes a decrease in river length and a local increase in slope. Because of an increase in slope, higher flow velocities and greater sediment transport will result and upstream degradation will occur. This increase in velocity and sediment transport probably occurred at Dry Creek because slope increased from .00448 feet per foot to .0073 feet per foot from 1962 to 1983 (Finney, 1983). Therefore, the cut-offs are probably partially responsible for the degradation occurring at the big-bend of Dry Creek near Finney Farm.

Both meander cut-offs and the gravel removal

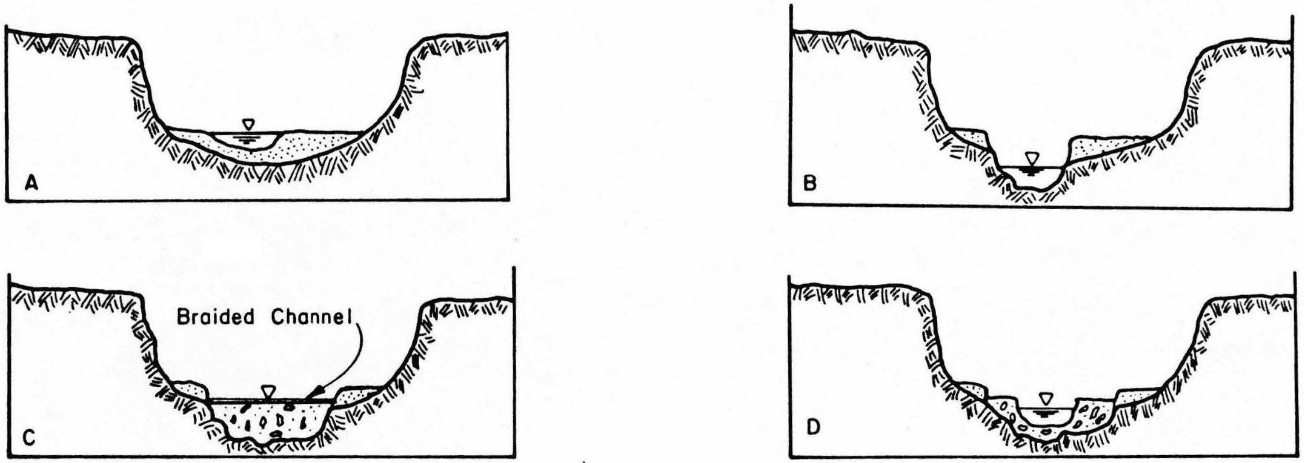

Figure16.

Diagrammatic cross sections of experimental channel 1.5 m from outlet of drainage system (base level) showing response of channel to one lowering of base level.

A. Valley and alluvium, which was deposited during previous run, before base level lowering. The low width-depth channel flows on alluvium.

B. After base level lowering of 10 cm, channel incises into alluvium and bedrock floor of valley to form a terrace. Following incision, bank erosion widens channel and partially destroys terrace (Figure 2C).

C. An inset alluvial fill is deposited, as the sediment discharge from upstream increases. The high width-depth ratio channel is braided and unstable.

D. A second terrace is formed as the channel incises slightly and assumes a low width-depth ratio in response to reduced sediment load. With time, in nature, channel migration will destroy part of the lower terrace, and a flood plain will form at a lower level.

(from S.A.Schumm. "Geomorphic Thresholds and Complex Response of Drainage Systems." In Maria Morisawa (Ed.), Fluvial Geomorphology, New York: Publications in Geomorphology, 1973).

occurred downstream from the Finney Farm causing upstream degradation. Man can also act as an external stimulus in creating degradation downstream. Causes of downstream degradation by man are construction of a dam, a change in land-use, or a diversion of flow. These causes would affect discharge, size of bed material, and bed material discharge. In the study of the Dry Creek drainage basin, the only cause applicable is land-use changes which would increase the surface run-off and subsequently the discharge. However, after examining the aerial photographs, it appears that land-use(primarily agricultural) has not changed significantly enough in the last twenty years to cause the sudden change in the stability of Dry Creek.

CONCLUSION

Many variables interact to contribute to erosion in a river system but an external stimulus is needed to cause it. In the Dry Creek river basin the two most important external influences were the removal of gravel from the stream and a shortening of channel length by cutting off meanders. These factors caused upstream degradation, especially in the Finney Farm area. As the degradation increased, the system reached a geomorphic threshold resulting in increased instability in the river basin.

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